(12) UK Patent Application (19) GB (11) 2 168 150 A

(43) Application published 11 Jun 1986

(21) Application No 8528864

(22) Date of filing 22 Nov 1985

(30) Priority data
(31) 8430701 (32) 5 Dec 1984 (33) GB

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(51) INT CL[4]
G01N 9/24 G01F 23/00 G01N 23/12 29/02

(52) Domestic classification (Edition H):
G1G 6H 6S 9X PK PL
G1A A3 BA D10 G17 G1 G2 G6 R2 S10 T15 T20 T2 T8
U1S 1269 2158 G1A G1G

(56) Documents cited

GB A 2137348	GB 1555549	GB 0809681
GB A 2128326	GB 1531729	EP A2 0028114
GB A 2076536	GB 1372724	US 4320659
GB A 2019558	GB 0873538	US 4203324

(58) Field of search
G1A
G1G
Selected US specifications from IPC sub-classes G01F G01N

(54) Pipeline inspection

(57) The nature of the flow pattern in a pipeline carrying both a liquid and a gas is characterised by measuring the void fraction or the average density along at least one chord across the pipeline (12) and by determining the distribution of liquid around the periphery of the pipe wall. The average density or void fraction may be measured by the absorption of gamma rays from a source (14); while the peripheral distribution may be determined from the attenuation of ultrasonic plate waves propagating through sectors of the wall between transmitters (18) and receivers (20), whereby the presence or absence of liquid is detected.

Fig.5.

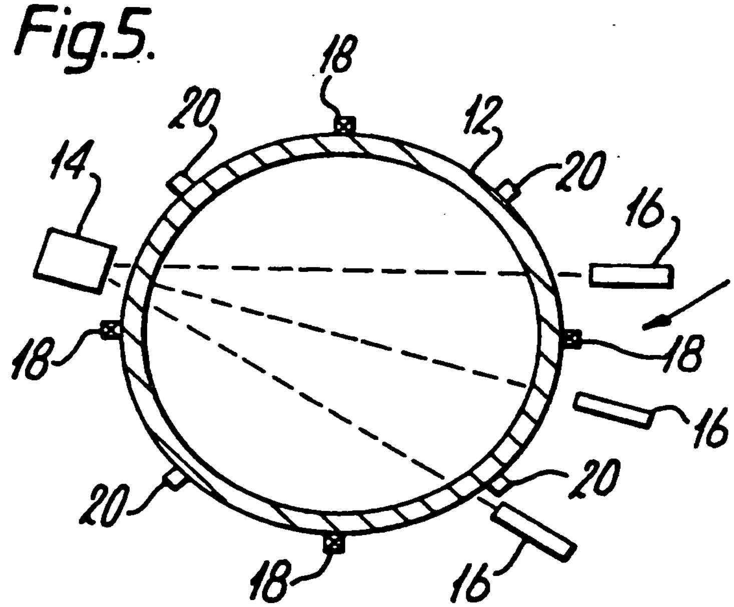

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Fig.1.

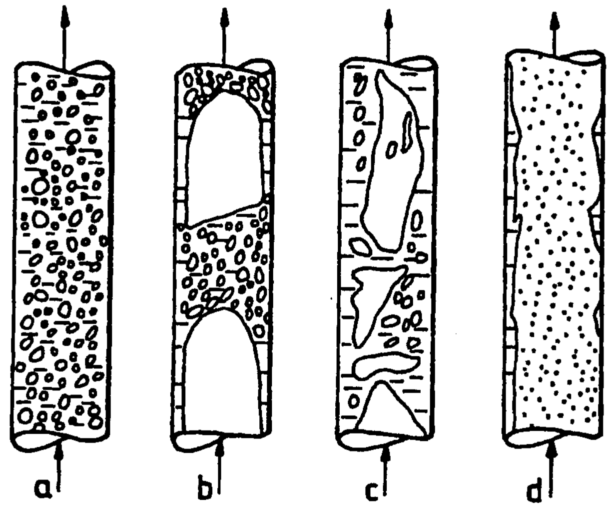


Fig.2.

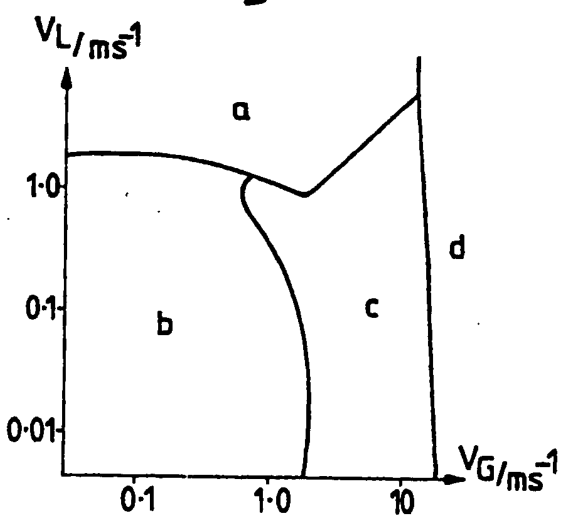


Fig.3.

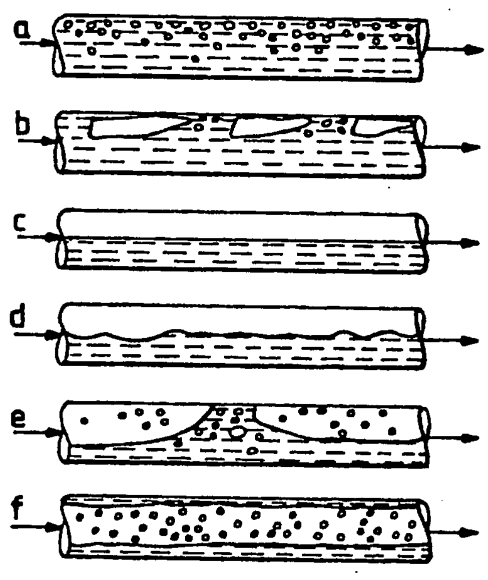


Fig.4.

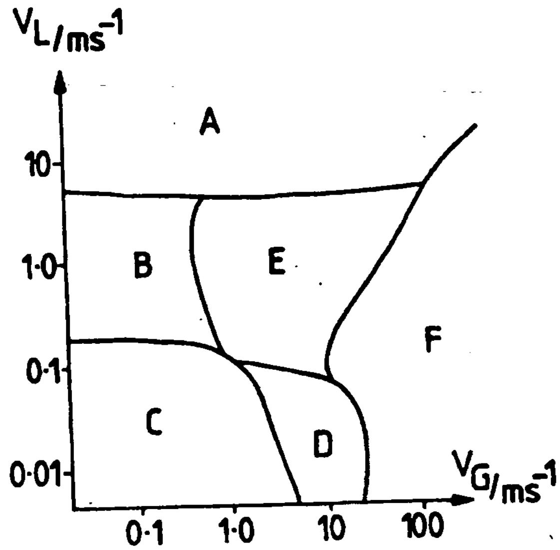
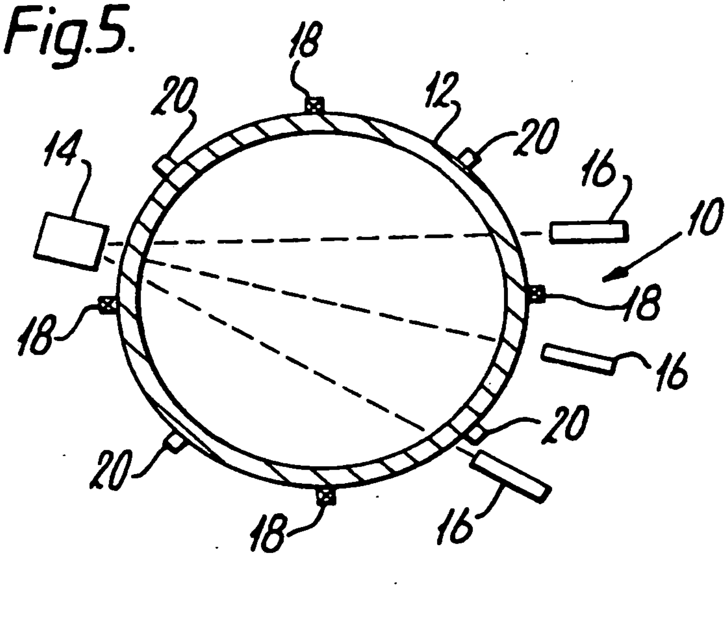

V_L/ms^{-1}
A
10
B
E
1·0
F
0·1
C
D
0·01
V_G/ms^{-1}
0·1
1·0
10
100

Fig.5.


18
20
12
20
14
16
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18
16
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20
18
16

SPECIFICATION

Pipeline inspection

The invention relates to a method and an apparatus for the inspection of pipelines to obtain information about their contents.

The invention is particularly applicable to the inspection of pipelines carrying both a gas and a liquid, in which the nature of the flow depends upon the flow rates of the two components, ranging from small bubbles of gas dispersed in the liquid, to a thin peripheral layer of liquid around the wall of the pipeline.

According to the present invention there is provided a method of inspection of a pipeline carrying a liquid to characterise the contents thereof, the method comprising measuring the average density along at least one chord across the pipeline, and determining the distribution of liquid around the periphery of the pipeline.

The average density is preferably measured along a plurality of chords across the pipeline; and can be measured from the attenuation of gamma rays, X–rays or neutrons.

The peripheral distribution of the liquid is preferably determined by detecting the presence or absence of liquid at a plurality of locations around the periphery of the pipeline. This may be achieved using ultrasonic waves; either by causing ultrasonic compression waves to propagate through the wall of the pipeline and detecting the amplitude of the wave reflected at the inner surface of the wall; or by causing ultrasonic plate waves to propagate from a transmitter along a portion of the wall, circumferentially or axially, and detecting the amplitude of the wave received at a receiver spaced apart from the transmitter.

The invention also provides an apparatus for performing the method of inspection.

The invention will now be further described by way of example only and with reference to the accompanying drawings, in which:

Figures 1a to 1d show diagrammatically flow patterns which can occur in a vertical pipeline;

Figure 2 shows graphically the gas and liquid flow velocities at which the flow patterns of Figs. *1a* to *d* occur;

Figure 3a to 3f, show diagrammatically flow patterns which can occur in a horizontal pipe;

Figure 4 shows graphically the gas and liquid flow velocities at which the flow patterns of Figs. *3a* to *f*, occur;

Figure 5 shows diagrammatically an apparatus for inspection of a pipeline.

When a gas–liquid mixture flows in a pipeline the two phases may define one of a variety of different patterns, the particular pattern depending on the physical properties of the liquid and the gas, the dimensions of the pipeline, and the flow rates of the two phases. The flow patterns are described for example in an article by Y. Taitel and A. E. Dukler, in A. I. Ch. E. Journal Vol. 22, No. 1 (January 1976); and an article by Y. Taitel, A. E. Dukler and D. Bornea in A. I. Ch. E. Journal Vol. 26, No.3 (May 1980).

Referring to Figs. 1*a* to *d*, the typical flow patterns where the gas and liquid flow upwardly in a verticle pipeline are shown. Fig. 1*a* shows "Bubble flow", in which the gas phase is distributed as discrete bubbles in a continous liquid phase. Fig. 1*b* shows "Plug flow", in which most of the gas forms large bullet-shaped bubbles almost as wide as the pipeline. Between these large bubbles and the wall is a thin liquid film falling downwards. Fig. 1*c* shows "Churn flow", in which the flow is much more chaotic, parts of the liquid phase alternating in their direction of flow and churning around. Fig. 1*d* shows "Annular flow", which is characterised by the continuity of the gas phase along the centre of the pipeline, and in which the liquid phase forms a thin film on the wall, with a wavy surface. Parts of the liquid phase may be in the form of droplets entrained in the gas, and in some circumstances these may form long foamy wisps.

Referring to Fig. 2 this indicates graphically the flow rates at which the flow patterns of Fig. 1 may occur, the graph axes representing the liquid superficial velocity (V_L) and the gas superficial velocity (V_G), and the letters *a* to *d* corresponding to the flow patterns of Figs. 1*a* to *d* respectively (see May 1980 reference above). The superficial velocity means the volumetric flow rate divided by the cross-sectional area of the pipeline.

Referring to Figs. 3*a* to *f*, typical flow patterns are shown for a horizontal pipeline; and Fig. 4 indicates graphically the superficial velocities V_L and V_G at which the flow patterns of Fig. 3 may occur (see January 1976 reference above). The letters A to F in Fig. 4 correspond to the flow patterns of Figs. 3*a* to *f*, respectively. Fig. 3*a* shows "Bubble flow", similar to that of Fig. 1*a* except that the bubbles of gas tend to flow in the upper part of the pipeline. Fig. 3*b* shows "Plug flow", similar to that of Fig. 1*b*. Fig. 3*a* shows"Stratified flow", in which the liquid and gas phases are completely separate, and the interface is smooth. At higher gas velocities waves begin to form on the liquid surface, forming "Wavy flow" as shown in Fig. 3*d*, and at still higher gas velocities some of the waves become large enough to reach the top of the pipeline, forming "Slug flow" as shown in Fig. 3*e*. These large waves or slugs are often frothy, and move along with the gas at high velocity. Fig. 3*f*, shows "Annular flow", which occurs at still greater gas velocities and is similar to that of Fig. 1*d*, differing in that the liquid film tends to be thicker at the bottom of the pipeline than the top.

The flow patterns described above have hitherto principally been studied using optical

techniques, in transparent pipelines. Such techniques are obviously inapplicable to practical pipelines for example for oil and natural gas mixtures, which are of steel with a wall thickness of over 10mm.

Referring now to Fig. 5, an apparatus 10 is shown for characterising the nature of the flow inside a pipeline 12, the pipeline 12 being shown in cross-section. The apparatus 10 comprises a gamma ray source 14 arranged to cause three beams of gamma rays to traverse the pipeline 12 along respective chords (shown as broken lines), and three gamma-ray detectors 16 arranged to detect the rays after their passage through the pipeline 12. The apparatus 10 also comprises four ultrasonic transmitters 18 and four ultrasonic receivers 20 mounted on the outside of the pipeline 12 equally spaced around its circumference, each receiver 20 being midway between two transmitters 18. Each transmitter 18 when energised causes ultrasonic plate waves (similar to a Lamb wave) to propagate in both directions around the wall of the pipeline 12, to be detected by the adjacent receivers 20. If a liquid layer of thickness greater than a few millimeters is present on the portion of wall through which propagation of the plate waves is taking place then mode conversion of the waves will occur, compression waves being generated in the liquid and the amplitude of the plate wave decreasing to zero within a propagation distance of a few wavelengths.

In operation of the apparatus 10 the gamma ray source 14 produces the three beams continuously and each of the three detectors 16 gives a continuous indication of the degree of absorption along the respective chord, and hence of the average density (or the void fraction) of the pipeline contents along the chord. Diametrical pairs of transmitters 18 are excited alternately, the amplitude of the signals detected by the receivers 20 indicating the presence or absence of a liquid layer on the portion of pipeline wall between the transmitter 18 and the receiver 20. Inspection of the indications given by the gamma ray detectors 16 and those given by the ultrasonic receivers 20 thus enables the distribution of liquid and gas within the pipeline 12, and its temporal variations, and so the nature of the flow pattern, to be determined. The apparatus 10 is non-invasive, and involves no modifications to the pipeline 12 itself, and so is applicable to practical pipe lines 12.

It will be appreciated that the number of chords along which the degree of absorption is measured might be fewer or more than three; that the orientation of the chords might be different from those shown in the Fig; and that the source 14 of gamma rays might be replaced by a source of x-rays or neutrons, the detectors 16 being changed accordingly.

It will be further appreciated that the numbers of ultrasonic transmitters 18 and receivers 20 might differ from that described; and the transmitters 18 might be arranged to cause the plate waves to propagate along the length of the pipeline 12 rather than circumferentially, the receivers 20 being repositioned accordingly.

A modification of the apparatus 10 includes two sets of transmitters 18 and receivers 20 spaced apart along the pipeline 12. Correlation of the indications given by the two sets enables the rate of movement of, for example, a liquid plug along the pipeline to be determined.

CLAIMS

1. A method of inspection of a pipeline carrying a liquid to characterise the contents thereof, the method comprising measuring the average density along at least one chord across the pipeline, and determining the distribution of liquid around the periphery of the pipeline.

2. A method as claimed in Claim 1 wherein the average density is measured along a plurality of chords across the pipeline.

3. A method as claimed in Claim 1 or Claim 2 wherein the peripheral distribution of the liquid is determined by detecting the presence or absence of liquid at a plurality of locations around the periphery of the pipeline.

4. A method as claimed in Claim 3 wherein the peripheral distribution is determined by causing ultrasonic compression waves to propagate through the wall of the pipeline and detecting the amplitude of the wave reflected at the inner surface of the wall.

5. A method as claimed in Claim 3 wherein the peripheral distribution is determined by causing ultrasonic plate waves to propagate from a transmitter along a portion of the wall, and detecting the amplitude of the wave received at a receiver spaced apart from the transmitter.

6. A method of inspection of a pipeline carrying a liquid to characterise the contents thereof substantially as hereinbefore described with reference to, and as shown in, Fig. 5 of the accompanying drawings.

7. Apparatus for inspecting a pipeline carrying a liquid to characterise the contents thereof, comprising means for measuring the average density along at least one chord across the pipeline, and the means for determining the distribution of liquid around the periphery of the pipeline.

8. Apparatus for inspecting a pipeline carrying a liquid to characterise the contents thereof substantially as hereinbefore described with reference to, and as shown in, Fig. 5 of the accompanying drawings.

Printed in the United Kingdom for
Her Majesty's Stationery Office, Dd 8818935, 1986, 4235.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.